Suppression of Heating of Coronal Loops Rooted in Opposite Polarity Sunspot Umbrae

Sanjiv K. Tiwari,

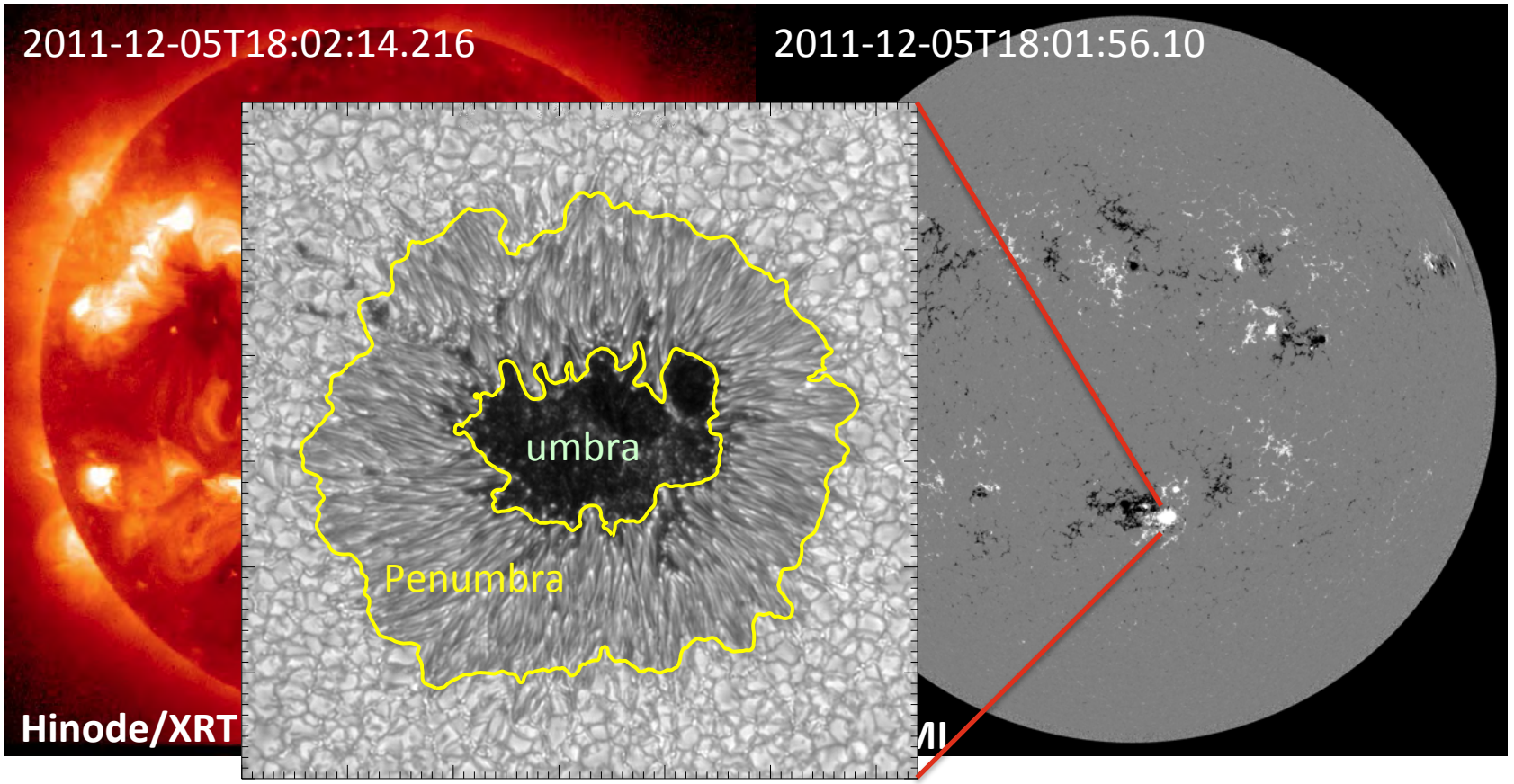
(J. K. Thalmann*, A. R. Winebarger, N. K. Panesar#, R. L. Moore#)

NASA Marshall Space Flight Center, Huntsville, AL, USA
*Institute for Physics/IGAM, University of Graz, Austria
#CSPAR, UAH, Huntsville, AL, USA

Marshall Space Flight Center

21 Jul 2015 **Loops VII, Univ. of Cambridge** **sanjiv.k.tiwari@nasa.gov**

Background



- Active regions are the brightest features in EUV and X-ray corona of the Sun
  Sounding rockets and Skylab (Vaiana et al. 1973, 1975) onwards….

Background..

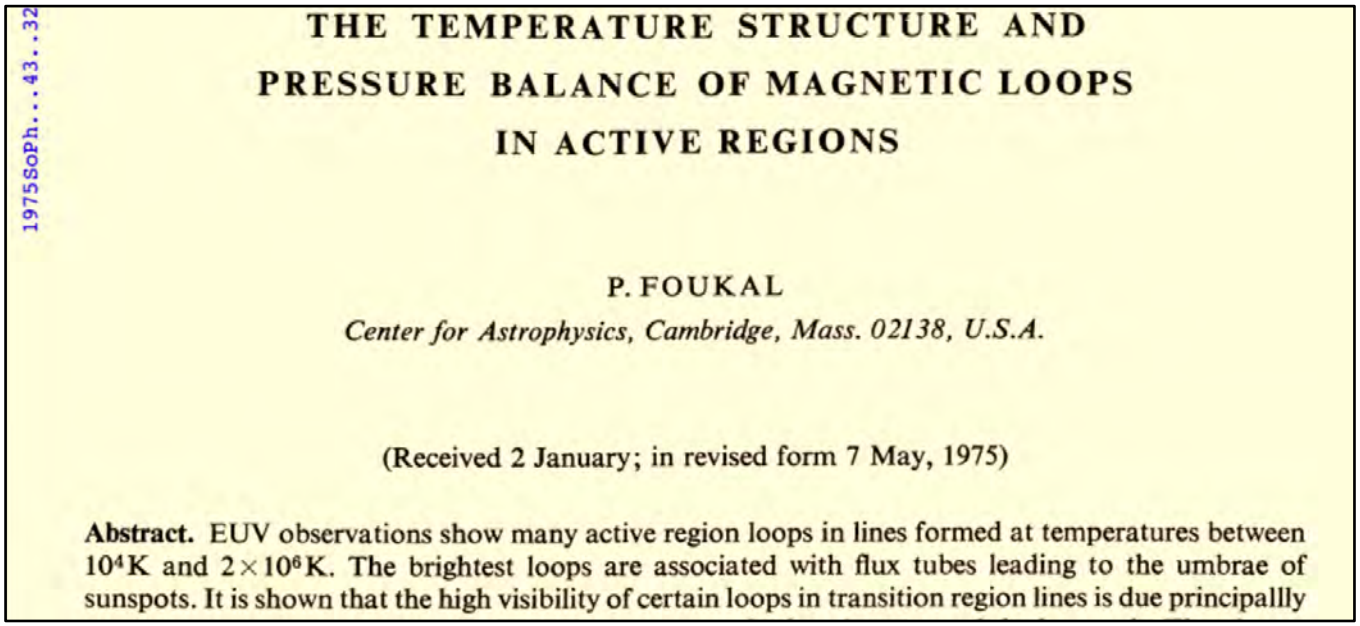
- Sunspots are dark on the surface and in the (X-ray) corona
  (Golub, Zirin & Wang, 1994: NIXT sounding rocket X-ray images)

- Sunspot umbrae have no or little X-ray and/or coronal EUV emissions
  (Pallavicini et al. 1979, Webb & Zirin 1981, Webb et al. 1983)

- None of the bright loops originate in sunspot umbrae
  (Sams III et al., 1992)

Inconsistent with the following…

- Loops rooted in sunspot umbra are the brightest ones among others
  (Foukal et al., 1974; Foukal, 1975; Webb & Zirin 1981)



1975SoPh...43..32

THE TEMPERATURE STRUCTURE AND PRESSURE BALANCE OF MAGNETIC LOOPS IN ACTIVE REGIONS

P. FOUKAL

Center for Astrophysics, Cambridge, Mass. 02138, U.S.A.

(Received 2 January; in revised form 7 May, 1975)

Abstract. EUV observations show many active region loops in lines formed at temperatures between 10^4K and 2×10^6K. The brightest loops are associated with flux tubes leading to the umbrae of sunspots. It is shown that the high visibility of certain loops in transition region lines is due principallly

Webb & Zirin 1981

- All flaring loops end in umbrae

Golub, Zirin & Wang, 1994

- The brightest features are the remains of small flares

Falconer et al. 1997

- Brightest loops are rooted near neutral lines
- Flux cancellation at feet might induce loop's coronal brightness

Some obvious questions

- Why sunspots, particularly umbrae, are usually dim in coronal EUV and X-ray?

- What's special about some loops that stem from an umbra but are the AR's brightest loops in coronal EUV and X-ray at a given time?

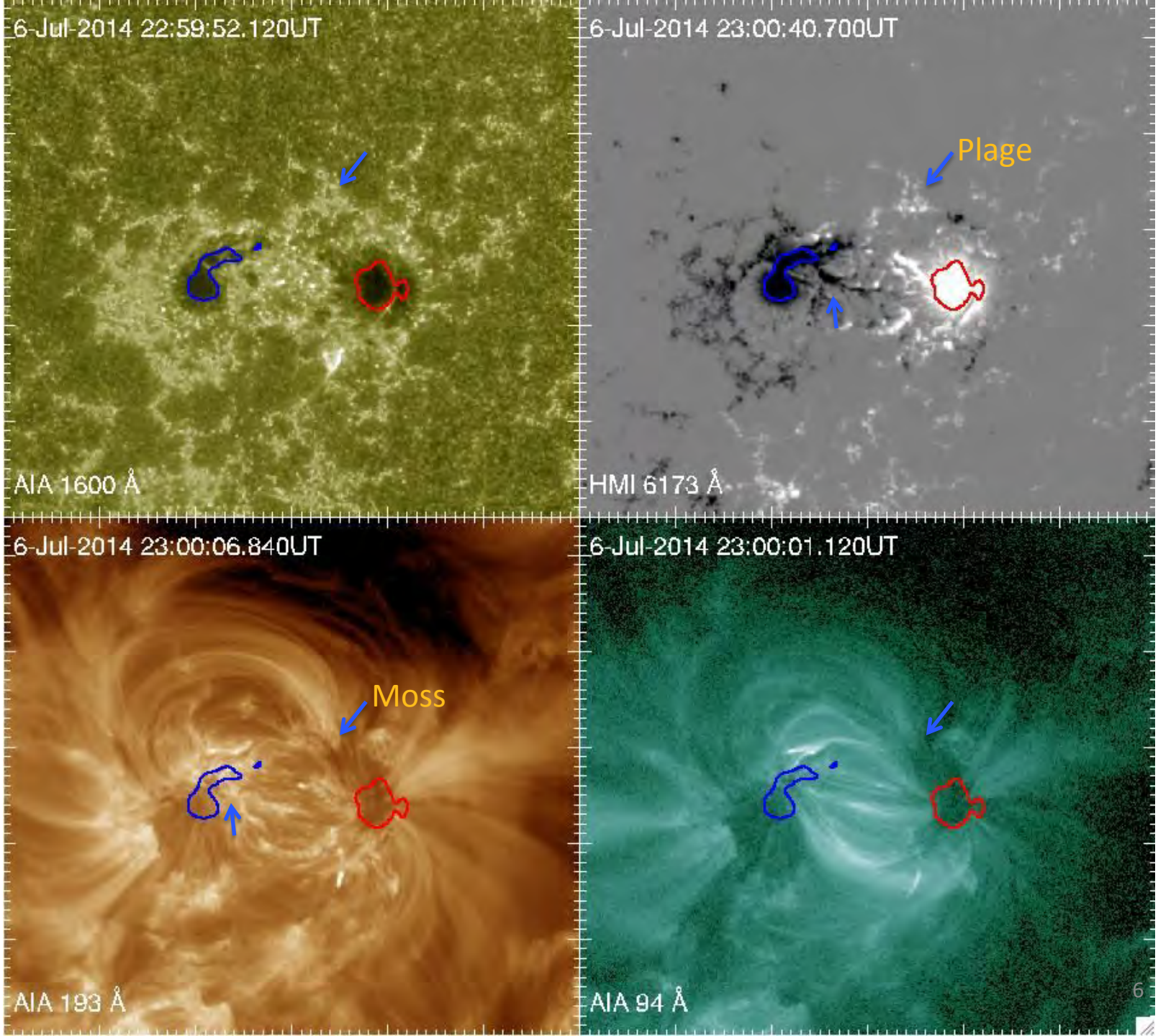
- Does loop's rooting pattern, magnetic setting on the photosphere, tell us something about their coronal brightness?

25h movie 6-7Jul 2014

@ 3m cadence

AR12110

E/W ± 7deg
S −15deg



AIA 94 Å movie reveals that:

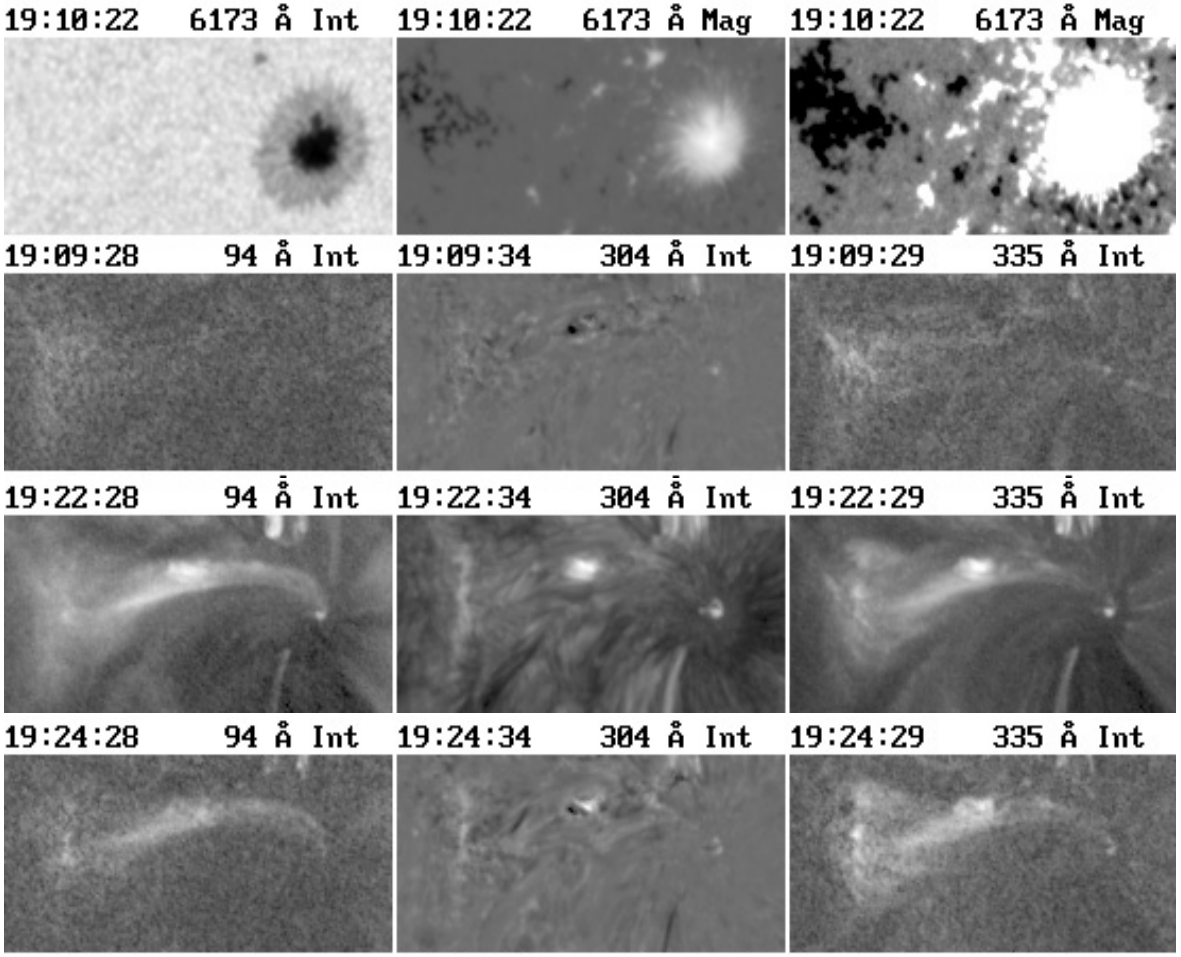
- Bright loops are episodic (~1-2h); repeated subflares are seen in sets of loops with indicative rooting pattern

- The brightest loops are rooted in umbra at one of their feet with their other foot in plage or penumbra of opposite polarity, and they never end in opposite polarity umbra.

- The plage-to-plage loops have only intermediate brightness

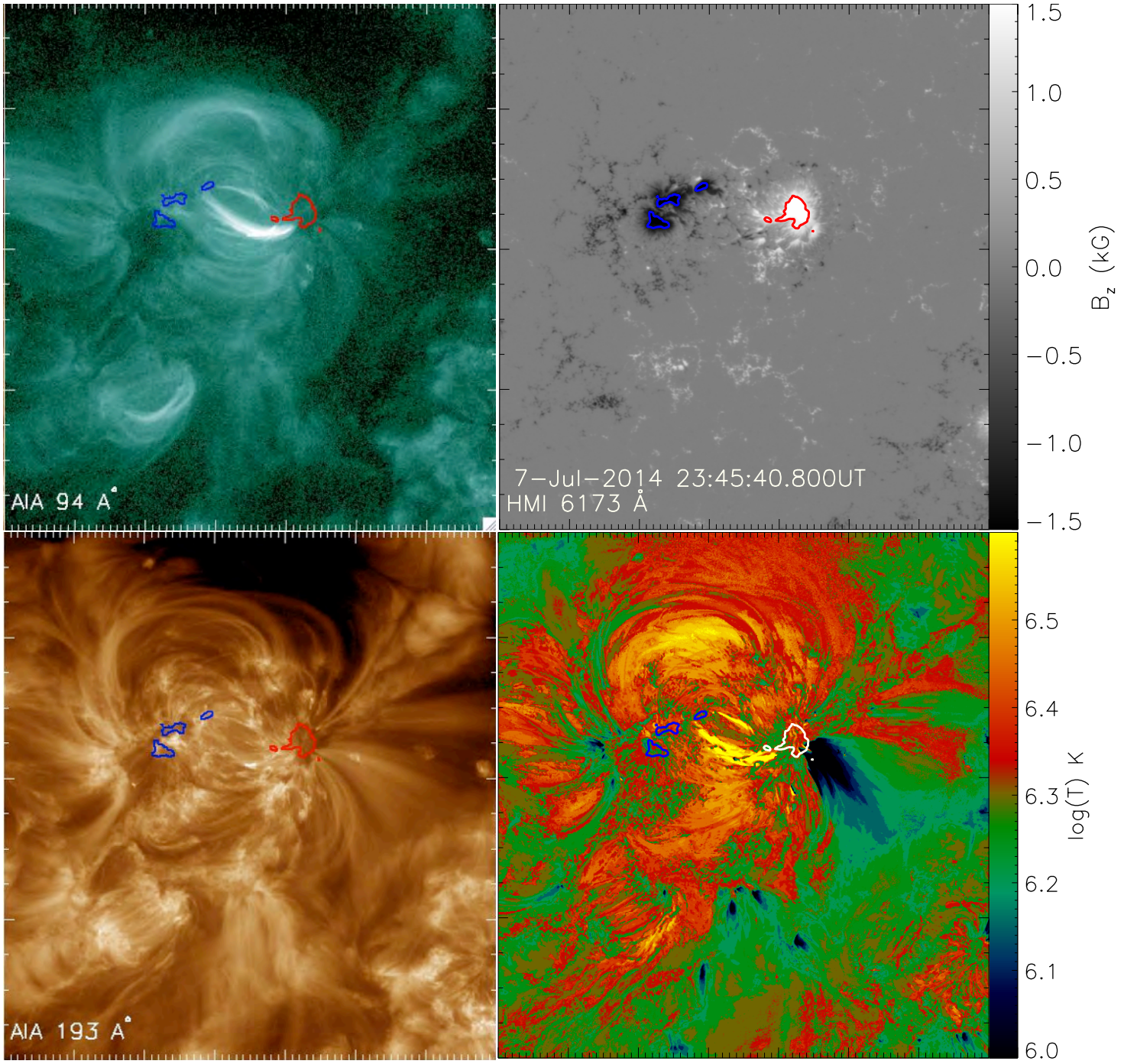
- AIA 94 images are dim in umbrae-> not all umbral loops are strongly heated; most umbral loops are weakly heated

- Transient loops (<30m life) follow the same pattern, i.e., the loops rooted in sunspot umbra are the hottest loops among others



from Alissandrakis & Patsourakos, 2013

Example


AIA 94 Å
7-Jul-2014 23:45:40.800UT
HMI 6173 Å
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
B_z (kG)
AIA 193 Å
6.5
6.4
6.3
6.2
6.1
6.0
log(T) K

Umbra-to-umbra loops?

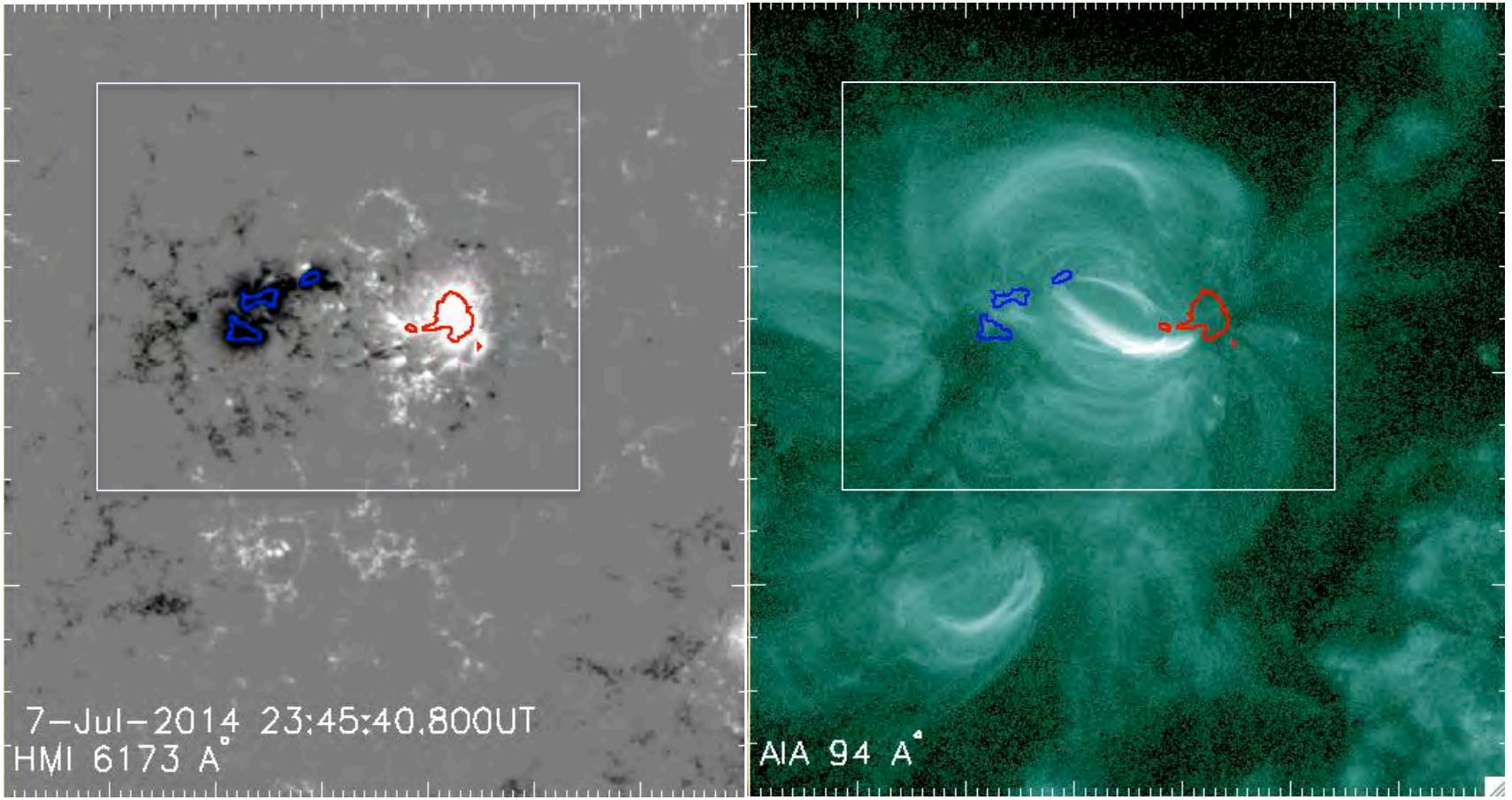
To test whether there are umbra-to-umbra coronal loops not visible in any AIA channel:

we performed a NLFFF extrapolation
(Wiegelmann et al. 2006; Wiegelmann & Inhester, 2010)

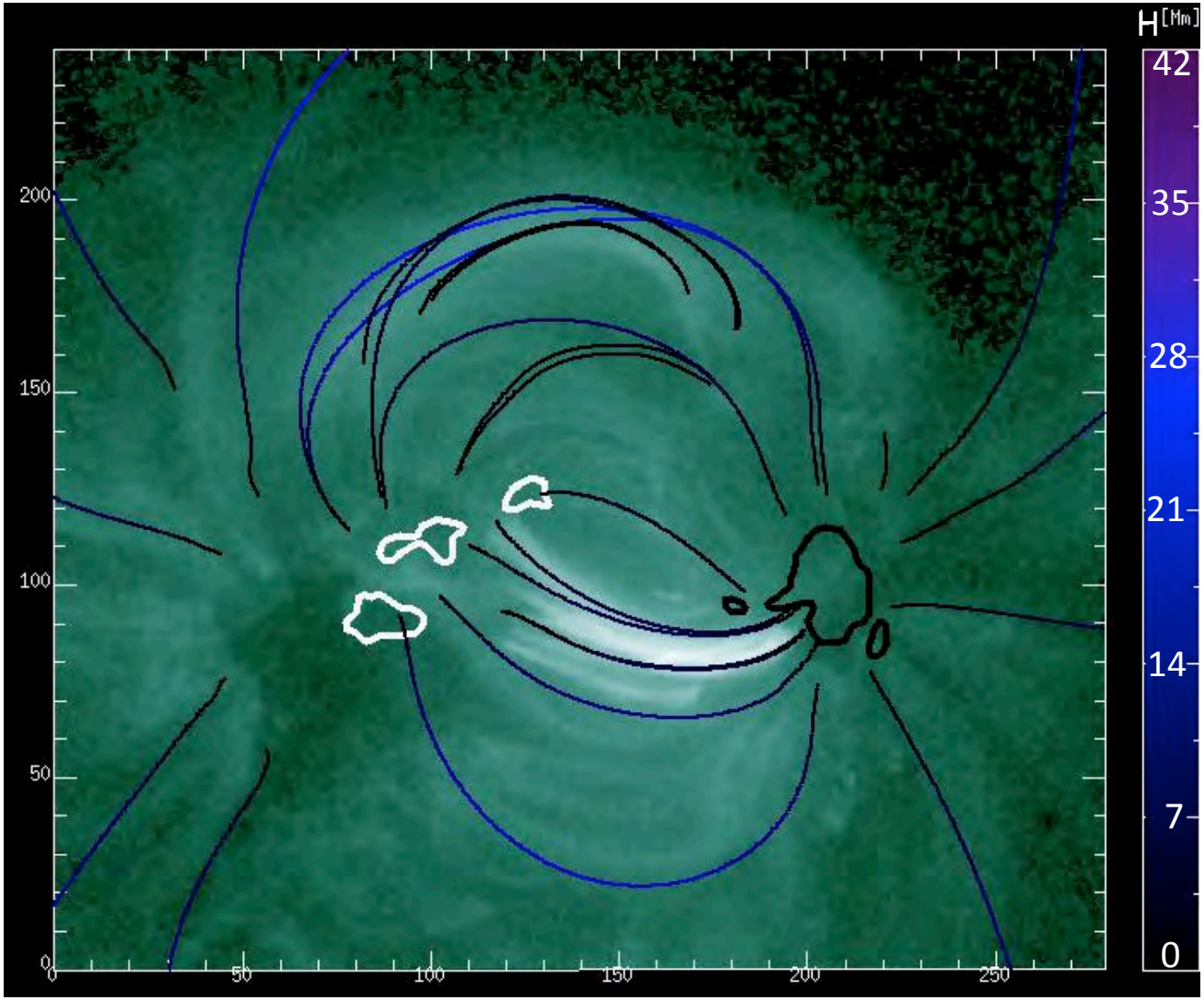
- preprocessing applied to HMI vector magnetograms to achieve force-free boundary conditions for the modeling

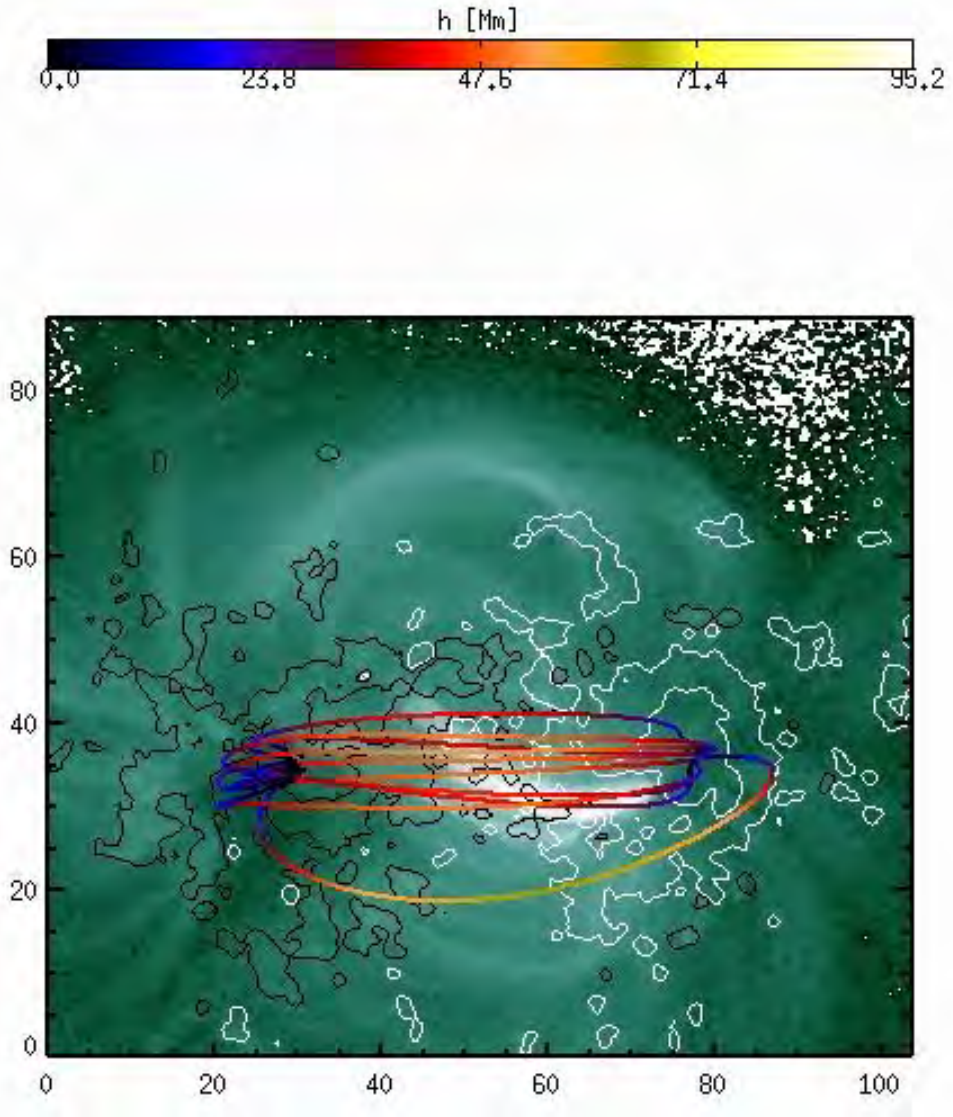
(performed by our collaborator Julia K. Thalmann)

FOV selected for the NLFFF extrapolation

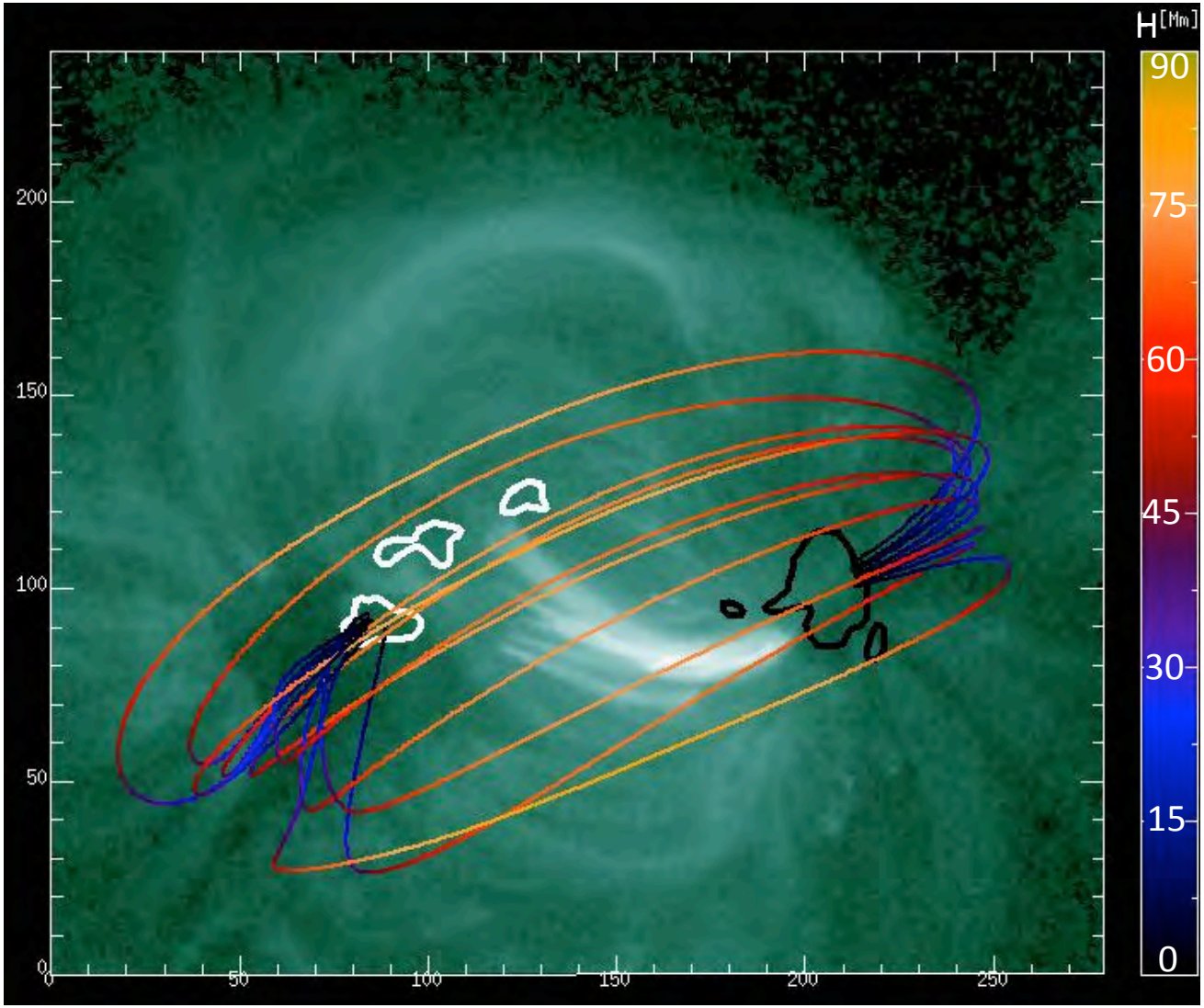


NLFF model field lines

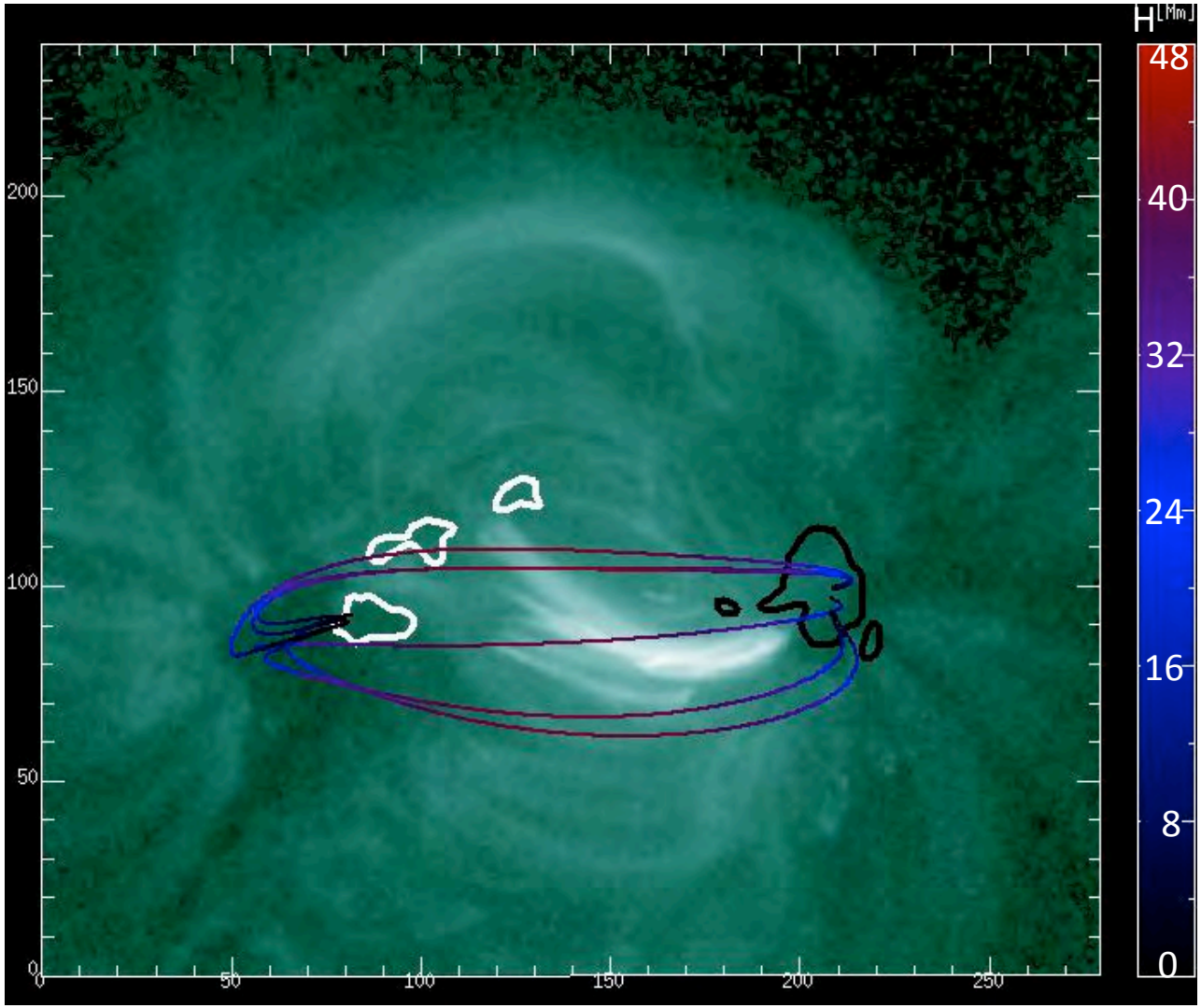



h [Mm]
0.0
23.8
47.6
71.4
95.2
0
20
40
60
80
0
20
40
60
80
100

Modeling results: high umbral loops

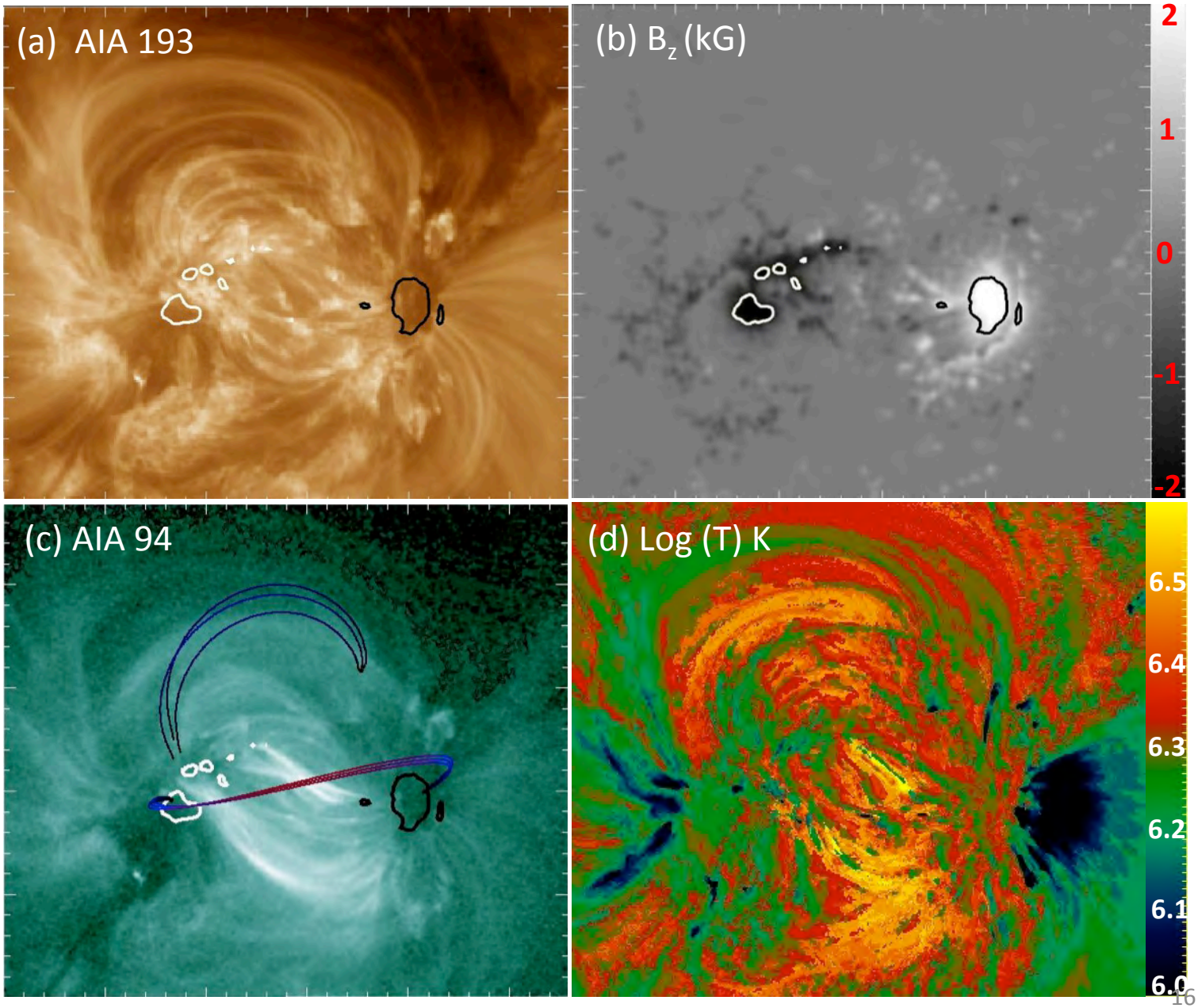


Modeling results: lower umbral loops



Example

07 Jul 2014 10:24 UT



Summary of the preliminary results

- Lack of coronal emission in umbra-to-umbra loops is new evidence supporting Parker's idea that convection at loop footpoints drives coronal heating in ARs

- Most of the brightest loops are transient (micro/sub-flaring loops) and have the following magnetic rooting pattern:
  -AIA 94 Å umbra-to-umbra loops have the weakest heating
  -Plage-to-plage loops have intermediate heating
  -Umbra-to-plage/penumbra loops have the strongest heating

Our hypothesis

Magnetic field strength together with the convective freedom at the feet of the loops determines their coronal temperature

- Umbra-to-umbra loops have the lowest temperature because they have least convective freedom at their feet, either to induce braiding in the coronal loops, or to generate Alfven waves.

- Only umbra-to-plage and/or penumbra loops have the highest temperature because they have strong magnetic field and one of their feet has moderate convection

- Plage-to-plage loops have only intermediate temperature because they have rather weaker field, although they have moderate convective freedom at their feet

Loop length is an important factor: work in progress!!

Thanks!